Level of Agricultural Mechanization in Oriental Mindoro, Laguna and Quezon, Philippines Using the Modified Agricultural Mechanization Index for Lowland Rice

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ABSTRACT

The Agricultural and Fisheries Mechanization Law of 2013 mandated the government to increase its support and investment for the distribution of agricultural mechanization technologies (AMTs) throughout the country in support of its food security and sufficiency programs. For an equitable distribution of AMTs, a standard protocol to determine the current level of mechanization expressed in terms of agricultural mechanization index was established, through the formulation of the Modified Agricultural Mechanization Index (MAMI). $MAMI_{rice}$ was established based on soil type, windows for each operation, operational hours per day, source of power for each operation, actual utilization of power source, the chemicals applied, crop care practices, crop water requirement, efficiency for each operation, rice variety, and yield per cropping season. $MAMI_{rice}$ was applied in determining the level of mechanization per farming operations in Oriental Mindoro, Laguna and Quezon provinces. Results showed that the level of mechanization in Oriental Mindoro were 1.013 hp/ha for operations mostly done by man-animal system, 3.029 hp/ha for operations involving man-machine system using plowing-harrowing and reaping-threshing, and 1.780 hp/ha for man-machine system that uses rototilling and rice combine harvesting. For Laguna, the level of mechanization was 0.745 hp/ha, 1.836 hp/ha and 1.232 hp/ha for man-animal system, man-machine system using plowing-harrowing and reaping-threshing, and man-machine system using rototilling and combine harvesting. For Quezon, the level of mechanization for man-animal system using plowing-harrowing and reaping-threshing was 2.646 hp/ha, 4.565 hp/ha for man-machine system, and 2.505 hp/ha for man-machine system using rototilling and combine harvesting. The values obtained for the three provinces were still way below the computed theoretical agricultural mechanization index, 5.071 hp/ha, that would yield at least 6 ton/ha. A computed agricultural mechanization index can be considered ideal if the target yield of 6 tons/ha is attained and utilization of the machines is efficient and not underutilized.

Keywords: agricultural mechanization, agricultural mechanization index, level of mechanization, MAMIrice

INTRODUCTION

The intervention on the purposive acceleration on the diffusion, adoption and utilization of Agricultural and Fisheries Mechanization Technologies (AFMTs) has always been one of the major flagship programs of the government as stipulated in Republic Act 10601 otherwise known as the Agricultural and Fisheries Mechanization (AFMech) Law of 2013. For any intervention to succeed, one has to determine the level of mechanization of a particular commodity to have a understanding of the intervention to be undertaken. The level of agricultural mechanization has always been the basis of agricultural mechanization intervention for the development of the agricultural and fisheries sector. The level of mechanization is usually represented by agricultural mechanization index (AMI) which is an indicative measure of the level of agricultural mechanization.

The need for the acceleration of the level of mechanization is linked to increasing demand of food from the ever growing population. However, there had been no standard methodology in the determination of the level of mechanization. ASEAN countries have different methodologies in computing the level of mechanization indicated by AMI. In the Philippines, institutions involved in the promotion of agricultural mechanization have also different methodologies in expressing the agricultural mechanization index of the country (Amongo *et al*., 2017a). Hence, there is a need for the development of modified agricultural mechanization index (MAMI). The protocol is expected to provide decision makers to have a basis in making well-informed decisions for the acquisition, distribution and utilization/adaption of agricultural mechanization technologies. The MAMI has been adopted as national policy by the Department of Agriculture in 2017 (DA-PCAF-PDCD-SCS-AFMeC-MEMO No. 17-076 to 17-078) determine the level of mechanization in the country. Furthermore, the MAMI will aid agricultural and biosystems engineering profession as partners of the government in projecting the level of mechanization for the development of the agricultural and fisheries sector.

SIGNIFICANCE OF THE STUDY

It is logical to have a significant value representing the level of agricultural mechanization of a country due to the critical importance of mechanization to agricultural development. The level of mechanization in the Philippines had been measured more commonly in terms of hp/ha for decades. Other common measures on the level of agricultural mechanization were in terms of degree of utilization and area coverage presented as percent utilization and percent area coverage of the different sources of power, such as, manual system, man-animal systems and man-machine systems per farm operation of specific crop as presented in the study conducted by AMDP-UPLB (1992). With the growing concern for sustainable energy utilization in the agricultural production systems, expressing the level of mechanization using the mechanization index in terms of energetics is gaining popularity. A study on the analysis of energy for different rice production system in the Philippines showed that the total energy input for irrigated transplanted rice was 13,920 MJ/ha while for rainfed transplanted rice was 11,969MJ/ha and the total energy input for irrigated direct seeded rice was 12,284MJ/ha while for rainfed direct seeded rice was 10,944MJ/ha (Bautista and Minowa, 2010).

Despite the existence of AMI values to express the level of mechanization in the Philippines, from 0.198 hp/ha in 1968 (RNAM, 1994) to 2.31 for rice–based farming system in 2013 (dela Cruz and Bobier, 2013), there had been no established and accepted standard methodology to measure AMI. The present AMI had provided a quantitative value to track the level of mechanization over the years. However, its rate of increase and improvement from one period to another, although quantifiable, employ different methods which may give values that may lead to different interpretations. There may have been similarities in the methodology employed by previous studies on the level of agricultural mechanization, but the parameters used were different from one method to another. For instance, the procedure used by Rodulfo, *et al*. (1998) and dela Cruz and Bobier (2013) considered man, animal and machine as source of power, while the

procedure employed by the Regional Network for Agricultural Machinery (RNAM) in 1990 and Agricultural Machinery Manufacturers Distributors Association Foundation, Inc. (AMMDA) considered only the contribution of man-machine systems in the computation of hp/ha (Panagsagan, 2011). Aside from the numerical value of agricultural mechanization index, Franco et al. (2001) expressed the level of mechanization qualitatively as low, intermediate, high and full mechanization level depending on the AMTs used in certain farm operation.

Given the disparity on how the hp/ha value were derived, a standard methodology to continually monitor the level of agricultural mechanization that will indicate an acceptable and understandable value is warranted. A meaningful level of agricultural mechanization should represent important attributes to answer the question as to "What does the AMI represent and what purpose does it serve?", hence, MAMI was formulated and was validated to determine its effectiveness.

OBJECTIVES

The general objective of the study was to validate the formulated Modified Agricultural Mechanization Index equation for lowland rice producing areas in the provinces of Oriental Mindoro, Laguna and Quezon. The specific objectives were to:

1. gather parameters needed in the computation of $MAMI_{rice}$ on selected rice-producing municipalities in the provinces of Oriental Mindoro, Laguna and Quezon;
2. determine the rate of work of technology used in calculating $MAMI_{rice}$; and
3. compare the obtained results of the $MAMI_{rice}$ in Oriental Mindoro, Laguna and Quezon.

MATERIALS AND METHODS

Determination of $MAMI_{rice}$

The operational procedure on the computation of the Modified Agricultural Mechanization Index for lowland rice ecosystem or $MAMI_{rice}$ (Amongo et al., 2017a) was used in this study. Parameters such as soil type, windows for each operation, operation hours per day, source of power for each operation, actual utilization of the source of power, the chemicals applied, crop care practices, crop water requirement, efficiency for each operation, rice variety, and yield per cropping season were considered in the equation. The value of parameters depends on the site and was affected by the AMTs used and cultural practices of the farmers. The MAMI computed may increase or decrease through time, depending on the situation. The value of MAMI may increase if additional AMTs was used in certain areas. For instance, in Masbate, the package of UPLB corn mechanization technologies from production to post-production operations diffused and utilized in the area (Amongo et. al., 2017b), may contribute an increase in the value of MAMI in the province. On the other hand, the value of MAMI may decrease if the AMTs previously accounted in rice farming were not anymore utilized due to any factors and no other AMTs were added. MAMI is not cumulative over time because machines have certain service life.

The operations considered in rice farming were classified as land preparation, crop establishment, crop care, harvesting, drying, hauling and milling. In rice milling, only village level or the one that were owned by farmer's cooperative were considered. The large rice milling facilities owned and operated by private sectors were not considered since the objective was to determine the agricultural mechanization index at farmer's level. If the farmer sold his/her produce just after harvest, then the succeeding operation/s were not considered in the equation. The general equation for $MAMI_{rice}$ is presented in Equation 1 where the power source coming from machine, draft animal, and human were considered for each farm operation. If not all power sources were used on a certain farm operation, it will just be omitted from the general equation. In the equation, in the human power is included in the machine power and draft animal power since it is still needed to operate the machine and to guide the draft animal when doing farm activities.

$$MAMI_{rice} = \left(\frac{A_{T-farmer}}{A_T}\right)\left[\left\{\frac{\sum[P_{machine} + (\#\ of\ operator \times P_{man})]}{\sum A_{T-machine}}\right\}_{for\ each\ farm\ operation} + \left\{\frac{\sum[(\#\ of\ draft\ animal \times P_{animal}) + (\#\ of\ operator \times P_{man})]}{\sum A_{T-aimal}}\right\}_{for\ each\ farm\ operation} + \left\{\frac{\sum(\#\ of\ operator \times P_{man})}{\sum A_{T-manual}}\right\}_{for\ each\ farm\ operations}\right]_{farmer} + \left(\frac{A_{T-CHS}}{A_T}\right)\left[\left\{\frac{\sum[P_{machine} + (\#\ of\ operator \times P_{man})]}{\sum A_{T-machine}}\right\}_{for\ each\ farm\ operation} + \left\{\frac{\sum[(\#\ of\ draft\ animal \times P_{animal}) + (\#\ of\ operator \times P_{man})]}{\sum A_{T-aimal}}\right\}_{for\ each\ farm\ operation} + \left\{\frac{\sum(\#\ of\ operator \times P_{man})}{\sum A_{T-manual}}\right\}_{for\ each\ farm\ operations}\right]_{CHS\ provider}$$

Equation 1

where:

$MAMI_{rice}$ – modified agricultural mechanization index for lowland rice ecosystem, *hp/ha*
$P_{machine}$ –power rating of machine, *hp*
P_{man} – power rating of human, *hp*
P_{animal} – power rating of draft animal, *hp*
$A_{T\text{-}machine}$ – total area covered by machine for one cropping season, *ha*
$A_{T\text{-}man}$ – total area covered by human for one cropping season, *ha*
$A_{T\text{-}animal}$ – total area covered by draft animal for one cropping season, *ha*
$A_{T\text{-}farmer}$ – total area covered by farmers for one cropping season, *ha*
$A_{T\text{-}CHS}$ – total area covered by custom hiring service providers for one cropping season, *ha*
A_T – total area covered or the combination of total area covered by farmers and custom hiring service providers for one cropping season, *ha*

According to Campbell (1990), a water buffalo weighing 400 to 900 *kg* with an average speed of 2.9 to 3.2 *kph* had an approximate draft of 50 to 80 *N* and can develop around 0.75 *hp.* A cow or cattle weighing 400 to 600 *kg* with an average speed of 2.5 *kph* had an approximate draft of 50 to 60 *N* and can develop 0.45*hp*. On the other hand, a light horse weighing 400 to 600 *kg* with an average speed of 3.6 *kph* had an approximate draft of 60 to 80 *N* and can develop 1 *hp.* Meanwhile, a human weighing around 60 to 90 *kg* at an average speed of 1 *kph* can develop an approximate draft of 30 *N* and can develop 0.1 *hp.* Draft animal and human power were affected not only by its weight and age but was also affected by time and condition during the operation.

The parameters that were common in almost all rice farming operations in the computation of $MAMI_{rice}$ were the field capacity, *C*, area coverage per day, A_{day}, and the area covered per cropping season, A_T. Field capacity is the duration to perform a certain farm operation in a given area which is expressed in hectare per hour (*ha/h)*. The area coverage per day referred to the total area covered for a certain farm operation for one man-day whether the power source used in the operation came from man, man-animal, or man-machine. Only the productive time for the whole day of the farmer was considered in one man-day. The area covered per cropping season was the total area that will be covered in a certain operation if the power source will be utilized for the whole window of operation. This area does not always reflect the physical area covered by the equipment because some farm operations were done several times within the same area for each cropping season.

The information needed to compute the $MAMI_{rice}$ will be obtained primarily from the farmers and custom hiring service (CHS) providers of agricultural machinery via survey. Two sets of respondents were considered to get the needed information. First set of respondents were the group of farmers and the other one were the CHS providers. If the farmer hires agricultural machines from CHS providers to perform some farm operations, the power available to perform that operation will not be credited to the farmer. Instead, it will be credited to the CHS provider. This will avoid the possible multiple counting of agricultural machines that were used in the farm because in fact, only the CHS provider owns the machine.

Formulation and Pre-Testing of Test Instrument

The survey questionnaire that was used in the survey was formulated in such a way that all parameters needed in the computation of $MAMI_{rice}$ was attainable. The test instrument was subjected to pre-testing in Batac, Ilocos Norte and Naic, Cavite to further enhance the instrument for the actual survey.

Survey Site and Sample Size Determination

Stratified random sampling was used in the determination of the sample size. Stratified random sampling is a method of sampling that involves the division of a population into smaller groups known as strata. The strata are formed based on members' shared attributes and characteristics. A random sample from each stratum is taken in a number proportional to the stratum's size when compared to the population. These subsets of the strata are then pooled to form a random sample. The main advantage of stratified random sampling is how it captures key population characteristics in the sample. Similar to a weighted average, this method of sampling produces characteristics in the sample that are proportional to the overall population (Thompson, 2012).

Applying the stratified random sampling to the validation survey with a 95% level of confidence and a confidence interval of ±2%, both Oriental Mindoro and Laguna had 95 respondents each while Quezon had 96 respondents. The distribution of respondents in Oriental Mindoro was 13, 38 and 44 for small, medium and large production areas, respectively. In Laguna, the distribution was 13, 30 and 52 respondents for small, medium and large production areas. In the province of Quezon, the distribution of respondents was 7, 22 and 67 for small, medium and large production areas, respectively (Table 1).

Survey for the Determination of $MAMI_{rice}$

Upon finalization of the survey instrument and determination of sample size and site selection, actual survey was conducted in 2015, 2017, and 2018 in Oriental Mindoro, Laguna, and Quezon. The data gathered in the survey was analysed to determine the level of agricultural mechanization index in the three provinces using $MAMI_{rice}$.

RESULTS AND DISCUSSION

The $MAMI_{rice}$

The $MAMI_{rice}$ equation was used in the determination of agricultural mechanization index of the three (3) provinces. The agricultural machinery and labor services owned or provided by the farm owner or farmer and those that came from custom hiring service providers were included in the equation. Aside from presenting the total agricultural mechanization index, it was also presented in terms of farm activities so that it can easily be identified whether the contribution to the total agricultural mechanization index really came from machines or from draft animals or human power. Presenting the agricultural mechanization index by farm activities will also determine whether a certain operation needs to be mechanized.

Land Preparation

Land preparation in lowland rice cultivation does not only mean tilling of land. It may also involve dike repair and soaking the land in preparation for tilling and levelling the field after tilling in preparation for crop establishment. The common land preparation operations being conducted in the validation site were plowing, harrowing and

rototilling. The conventional way of performing these activities are done using draft animal, hand tractor or four-wheel tractor.

Crop Establishment

From the conducted survey, it was observed that the rice farmers in the three provinces prefer manual method of crop establishment. The respondents prefer manual transplanting in Laguna and Quezon and manual seeding and manual transplanting in Oriental Mindoro. Manual seeding was performed through broadcasting of rice seeds. Some of the farmers doing manual transplanting were hired laborers.

Mechanical ways of crop establishment was not popular in the province because of its weather condition. There were times that the rice farmers had properly established the rice but when strong typhoon or heavy rain hit the province, the newly grown rice where being washed out. Because of these experiences, the respondents prefer to do it manually and some opted to do it through broadcasting to minimize the cost.

Because the crop was established manually, it was observed that the crop stand and its plant density were not uniform which affects yield. Proper planting of rice will contribute to increase in yield because of increase in plant density per unit area and uniform crop stand will be achieved. Based from the result of the survey, mechanization effort was still needed in crop establishment. Aside from mechanical rice transplanter, a focus on

Table 1. Sample sites and respondent's distribution.

PROVINCE	MUNICIPAL-ITIES	RICE PRO-DUCTION AREA (ha)	% AREA DISTRI-BUTION	NUMBER OF RESPOND-ENTS
Oriental Mindoro	Small Production Area			
	Socorro	4,238.0	13.46%	6
	Baco	4,643.0		7
	Medium Production Area			
	Bongabong	10,927.0	40.86%	19
	Calapan City	16,034.0		19
	Large Production Area			
	Naujan	30,136.5	45.68%	44
Laguna	Small Production Area			
	Famy	305.0	10.31%	2
	Kalayaan	415.8		3
	Pakil	435.7		4
	Magdalena	438.6		4
	Medium Production Area			
	San Pablo City	558.4	28.86%	4
	Luisiana	563.8		4
	Pagsanjan	599.7		4
	Nagcarlan	605.4		4
	Majayjay	663.8		4
	Cabuyao	718.5		5
	Lumban	757.0		5
	Large Production Area			
	Calamba City	809.0	60.83%	5
	Siniloan	887.8		5
	Mabitac	1022.5		6
	Bay	1048.6		6
	Sta. Cruz	1269.1		7
	Pila	1400.9		8
	Sta. Maria	1415.2		8
	Calauan	1559.7		9
Quezon	Small Production Area			
	Plaridel	114.5	2.04%	3
	Sampaloc	270.0		4
	Medium Production Area			
	Gumaca	532.7	15.07%	4
	Atimonan	590.5		5
	San Antonio	789.9		6
	Mauban	926.6		7
	Large Production Area			
	Lucban	1213.5	82.89%	5
	Pagbilao	1303.0		6
	Tiaong	1644.0		7
	Tayabas City	2016.3		9
	Lucena City	2182.5		9
	Candelaria	3226.1		14
	Sariaya	4037.2		17

mechanized broadcaster must be taken into consideration since majority of rice farmers in Oriental Mindoro prefer to do crop establishment by direct seeding.

Crop Care

Crop care in rice production was observed to vary from one area to another. There were no common practices in the three sites surveyed. Crop care was categorized into chemical application, weeding and irrigation. Chemical applications includes application of fertilizer, whether liquid or granules, pesticide, fungicide, rodenticide and molluscicide. Some farmers do not regularly apply fertilizers. Majority of the farmers based their fertilizer application on the color of the leaves. If the color of the leaves of the rice was green, then they limit the application of fertilizer. Application of other chemicals depends on the occurrence of pest present in the field. If there was no appearance of pest, then the farmers do not apply such chemicals for two reasons: to minimize chemical inputs and to reduce costs. Liquid chemicals were usually applied using knapsack sprayer. Mechanical weeding in the field was mostly done on the small dikes surrounding the land parcel where rice crops are grown. Weeds grown within the land parcel were usually eradicated by applying herbicides. When rice broadcasting method is applied where no definite row and hill spacing are established, mechanical weeders are not permitted to enter the field. Hence, herbicides are predominantly used by the farmers to eliminate weeds. Further, only irrigation using pump were considered in the equation since it uses power from prime mover. Those areas that were rainfed, irrigated by national and communal irrigation system are not considered in the computation. The common size of pump used by the farmers was the 4" x 4" centrifugal pump. The size of the pump contributes on irrigation efficiency.

Harvesting

Based form the rice harvesting machinery that was predominantly observed in the three provinces, the level of mechanization for this operation was high in Oriental Mindoro and Laguna wherein combine harvester is popular. In Quezon, mechanical thresher is popular although a handful of rice farmers were hiring combine harvester.

Survey results showed that manual reaping was commonly done by both the farmers and by hired laborers. Rice reapers were used only by farmer-owners and utilized only in their rice field. However, in the case of rice threshers, farmer-owners allow the use of their machines by the neighboring farms for a certain fee which is usually a percentage from the harvest being threshed. Rice combines that were present in the provinces were mostly owned by CHS providers.

Drying

Palay drying in the three provinces was mostly done by sun drying and only few used mechanical dryers. It was also observed that not all farmers dry their harvest. Majority of them sell their harvest to the traders just after harvesting. The CHS providers serve also as palay traders. Only a small portion of the harvest remains with the farmers and these portions were the ones subjected to sun drying.

Hauling

The hauling operation considered in the validation survey was only hauling of harvest from rice field to the nearest access road. This is only the most visible involvement of rice farmer in hauling operation. AMI in hauling operation was difficult to measure since not all farmers haul their produce from the rice field to the access road. Some farmers let the traders haul the harvest directly from the rice field. Small portion of the harvest remained with the farmer for family consumption and the rest were sold to traders. Efficiency of hauling was not considered since there was no literature available stating the efficiency to haul the harvest from rice field to the access road unlike the other rice farming operations where information on efficiencies were available. The common practice in the surveyed areas was hauling the harvest from rice field to the nearest access road either manually or with the use of cart pulled by carabao. If the rice field is near to access road, then the farmer preferred manual hauling through hired labor.

Level of Mechanization in Oriental Mindoro, Laguna and Quezon Using $MAMI_{rice}$

The agricultural mechanization index (AMI) is presented in terms of farm operation to easily determine which among the operations are still done by human or animal power and which among the operations are already mechanized. This may help planners where to focus their efforts in mechanizing the rice production system. Aside from AMI for every farm operations, it can also be presented as a total AMI, which will represent the level of mechanization for that area. Tables 2, 3 and 4 present the computed $MAMI_{rice}$ for each specific farm operation using man-animal, man-machine and man-machine (rototilling and combine harvesting) systems in the provinces of Oriental Mindoro, Laguna and Quezon. The developed survey instrument for the determination of $MAMI_{rice}$ was first conducted in the province of Oriental Mindoro in 2015. The same methodology and survey instrument in the original study of Amongo *et al.* (2017a) was used in the conduct of survey in the provinces of Laguna and Quezon, conducted by Deniega (2017), and Sumague (2018), respectively.

For the combination of man-animal system, the total $MAMI_{rice}$ was computed at 1.013 *hp/ha*, 0.762 *hp/*ha, and 2.646 *hp/ha* for Oriental Mindoro, Laguna and Quezon, respectively, as summarized in Table 5. The MAMI for each operation of each province were below the theoretical values except for crop care operation in Quezon province where the value is thrice the theoretical. This may due to the irrigation pump set which was not fully utilized by the farmers. Theoretical values were computed in such a way that the AMTs to be used for plowing and harrowing were 4W tractor, crop establishment was walk behind rice transplanter, chemical application was knapsack sprayer, weeding was manual weeder, irrigation was centrifugal pump set, harvesting was rice combine harvester, drying was flatbed dryer, hauling was draft animal with a cart, and milling was using a village level rice mill and the target yield should reach up to 6 *tons/ha*. The logic of presenting a theoretical value in the MAMI that intends the use of mechanical power for farm operations is not to totally displace those operations that were done manually, with the aid of draft animal or with appropriate small AMTs, but to present an ideal value of the level of mechanization, towards moving forward and not being limited to the traditional way of farming.

The total $MAMI_{rice}$ of the combination of man-machine system using the plowing-harrowing and reaping-threshing combination of operations for Oriental Mindoro, Laguna and Quezon were 3.029 *hp/ha*, 1.661 *hp/ha* and 4.565 *hp/ha,* respectively, as presented in Table 6. The land preparation operation in Oriental Mindoro was on the ideal range while the value on harvesting was above the theoretical value, the same as the land preparation and crop care operations in Quezon province. Upon evaluation of the result of the survey, the agricultural machinery used in some operations with above theoretical values was underutilized in such a way that even if there was still available windows of operation for the AMTs to operate, the owner of the AMTs opt not to fully utilize it. The level of mechanization in other operations had below theoretical values.

The total $MAMI_{rice}$ of the combination of man-machine system using rototilling and combine harvesting operations were 1.780 *hp/ha*, 1.232 *hp/ha* and 2.505 *hp/ha* for Oriental Mindoro, Laguna and Quezon, respectively as summarized in Table 7. Only the harvesting operation in Oriental Mindoro had an ideal value of theoretical MAMI. The crop care operation in Quezon had above theoretical value and upon evaluation the pump set in irrigation operation was underutilized in such a way that it was not fully used for the possible windows of operation. Other operations were below theoretical values.

The values with above theoretical value remarks should be analysed first to determine whether the AMTs used in that particular operation was properly utilized or not. For those operations that were below theoretical values, the level of mechanization can be increased by introducing appropriate agricultural machinery and other advance machineries to move forward. For those values with ideal remarks, any addition of agricultural machinery may only result to underutilization of the added agricultural machinery.

Table 2. Summary of the computed $MAMI_{rice}$ for each operation in Oriental Mindoro.

Farm Activities	Total Area Coverage per Cropping Season *ha*				$MAMI_{rice}$ *hp/ha*			
	Farmer	CHS Provider	Farmer	CHS Provider	Total Weighted	Man-Animal System	Man-Machine System	Man-Machine System (Rototiller and Rice Combine)
Plowing (Man-Animal)	14.08	-	0.234	-	*0.234*	0.234	-	-
Plowing (Man-Machine)	539.31	122.65	1.017	1.283	*1.066*	-	1.066	-
Harrowing (Man-Animal)	38.38	-	0.167	-	*0.167*	0.167	-	-
Harrowing (Man-Machine)	2186.49	85.68	0.294	0.328	*0.295*	-	0.295	-
Rototilling (Man-Machine)	182.03	162.75	0.335	1.041	*0.668*	-	-	0.668
Seeding (Man)	1156.80	-	0.008	-	*0.008*	0.008	-	-
Seeding (Man-Machine)	-	-	-	-	-	-	-	-
Transplanting (Man)	-	1166.32	-	0.049	*0.049*	-	0.049	0.049
Transplanting (Man-Machine)	-	-	-	-	-	-	-	-
Chemical Application (Man)	1158.80	-	0.011	-	*0.011*	0.011	0.011	0.011
Chemical Application (Man-Machine)	-	-	-	-	-	-	-	-
Weeding (Man)	1598.59	-	0.003	-	*0.003*	0.003	0.003	0.003
Weeding (Man-Machine)	-	-	-	-	-	-	-	-
Irrigation (Man-Machine)	5487.00	-	0.064	-	*0.064*	0.064	0.064	0.064
Reaping (Man)	7.00	82.42	0.114	0.144	*0.142*	0.142	-	-
Reaping (Man-Machine)	14.04	-	1.161	-	*1.161*	-	1.161	-
Threshing (Man)	-	-	-	-	-	-	-	-
Threshing (Man-Machine)	-	375.24	-	0.358	*0.358*	0.358	0.358	-
Combine Harvesting (Man-Machine)	-	1007.75	-	0.963	*0.963*	-	-	0.963
Hauling (Man)	-	2112.92	-	0.014	*0.014*	0.014	-	-
Hauling (Man-Animal)	3492.95	-	0.010	-	*0.010*	-	0.010	0.010
Hauling (Man-Machine)	-	-	-	-	-	-	-	-
Drying (Man)	128.66	-	0.012	-	*0.012*	0.012	0.012	0.012
Drying (Man-Machine)	-	-	-	-	-	-	-	-
				TOTAL $MAMI_{rice}$ *hp/ha*		**1.013**	**3.029**	**1.780**

Table 3. Summary of the computed $MAMI_{rice}$ for each operation in Laguna.

Farm Activities	Total Area Coverage per Cropping Season *ha*		MAMI$_{rice}$ *hp/ha*					
	Farmer	CHS Provider	Farmer	CHS Provider	Total Weighted	Man-Animal System	Man-Machine System	Man-Machine System (Rototiller and Rice Combine)
Plowing (Man-Animal)	31.96	-	0.330	-	***0.330***	0.330	-	-
Plowing (Man-Machine)	114.27	659.79	0.840	0.380	***0.448***	-	0.448	-
Levelling (Man-Animal)	1157.12	999.03	0.020	0.010	***0.015***	0.015	-	-
Harrowing (Man-Animal)	531.87	316.82	0.020	0.030	***0.024***	0.024	-	-
Harrowing (Man-Machine)	240.03	275.10	0.320	0.250	***0.283***	-	0.283	-
Levelling (Man-Animal)	101.43	2630.33	0.210	0.100	***0.104***	-	0.104	-
Rototilling (Man-Machine)	362.50	893.12	0.440	0.330	***0.362***	-	-	0.362
Seeding (Man)	-	-	-	-	**-**	-	-	-
Seeding (Man-Machine)	-	-	-	-	**-**	-	-	-
Transplanting (Man)	43.91	748.30	0.160	0.100	***0.103***	0.103	0.103	0.103
Transplanting (Man-Machine)	-	-	-	-	**-**			
Chemical Application (Man)	5180.00	6770.17	0.001	0.001	***0.001***	0.001	0.001	0.001
Chemical Application (Man-Machine)	-	-	-	-	**-**	-	-	-
Weeding (Man)	891.51	1062.63	0.009	0.024	***0.017***	0.017	0.017	0.017
Weeding (Man-Machine)	-	-	-	-	**-**	-	-	-
Irrigation (Man-Machine)	1300.25		0.027		***0.027***	0.027	0.027	0.027
Reaping (Man)	159.17	367.06	0.170	0.126	***0.139***	0.139	0.139	-
Reaping (Man-Machine)	-	-	-	-	**-**	-	-	-
Threshing (Man)	41.85	111.85	0.048	0.048	***0.048***	0.048	-	-
Threshing (Man-Machine)	322.23	839.42	0.536	0.337	***0.392***	-	0.392	-
Combine Harvesting (Man-Machine)	-	769.10	-	0.576	***0.576***	-	-	0.576
Hauling (Man)	343.14	113.22	0.030	0.110	***0.050***	0.050	-	-
Hauling (Man-Animal)	50.00	393.49	0.210	0.130	***0.139***	-	0.139	0.139
Hauling (Man-Machine)	-	-	-	-	**-**	-	-	-
Drying (Man)	64.80	455.59	0.015	0.006	***0.007***	0.007	0.007	0.007
Drying (Man-Machine)	-	-	-	-	**-**	**-**	**-**	**-**
			TOTAL MAMI$_{rice}$ *hp/ha*			**0.762**	**1.661**	**1.232**

Table 4. Summary of the computed $MAMI_{rice}$ for each operation in Quezon.

Farm Activities	Total Area Coverage per Cropping Season, *ha*		$MAMI_{rice}$ *hp/ha*					
	Farmer	CHS Provider	Farmer	CHS Provider	Total Weighted	Man-Animal System	Man-Machine System	Man-Machine System (Rototiller and Rice Combine)
Plowing (Man-Animal)	9.36	17.82	0.909	0.943	***0.931***	0.931	-	-
Plowing (Man-Machine)	104.85	162.50	1.377	1.492	***1.447***	-	1.447	-
Levelling (Man-Animal)	69.51	238.58	0.098	0.100	***0.100***	0.100	-	-
Harrowing (Man-Animal)	24.87	16.63	0.103	0.102	***0.103***	0.103	-	-
Harrowing (Man-Machine)	55.99	448.91	0.425	0.761	***0.724***	-	0.724	-
Levelling (Man-Animal)	25.52	135.85	0.713	0.303	***0.368***	-	0.368	-
Rototilling (Man-Machine)	50.55	354.35	0.633	0.350	***0.385***	-	-	0.385
Seeding (Man)	6.67	58.58	0.060	0.082	***0.080***	0.080	-	-
Seeding (Man-Machine)	-	-	-	-	**-**	-	-	-
Transplanting (Man)	8.56	568.85	0.140	0.113	***0.113***	-	0.113	-
Transplanting (Man-Machine)	-	19.10	-	0.298	***0.298***	-	-	0.298
Chemical Application (Man)	4483.24	6539.47	0.061	0.022	***0.031***	0.031	0.031	0.031
Chemical Application (Man-Machine)	-	-	-	-	**-**	-	-	-
Weeding (Man)	204.27	1577.35	0.005	0.017	***0.016***	0.016	-	-
Weeding (Man-Machine)	186.36	946.94	0.003	0.017	***0.015***	-	0.015	0.015
Irrigation (Man-Machine)	63.92	-	0.946	-	***0.946***	0.946	0.946	0.946
Reaping (Man)	93.21	2007.37	0.012	0.035	***0.034***	0.034	0.034	-
Reaping (Man-Machine)	-	-	-	-	**-**	-	-	-
Threshing (Man)	14.85	76.19	0.047	0.192	***0.168***	0.168	-	-
Threshing (Man-Machine)	31.72	811.64	0.662	0.554	***0.558***	-	0.558	-
Combine Harvesting (Man-Machine)	-	282.79	-	0.500	***0.500***	-	-	0.500
Hauling (Man)	24.24	49.20	0.008	0.264	***0.180***	0.180	-	-
Hauling (Man-Animal)	29.67	313.53	0.086	0.114	***0.112***	-	0.112	0.112
Hauling (Man-Machine)	-	-	-	-	**-**	-	-	-
Drying (Man)	6.31	7.47	0.079	0.040	***0.058***	0.058	-	-
Drying (Man-Machine)	-	66.00	-	0.218	***0.218***	-	0.218	0.218
			TOTAL $MAMI_{rice}$ *hp/ha*			**2.646**	**4.565**	**2.505**

Table 5. Summary of the computed $MAMI_{rice}$ in man-animal system on the three provinces.

Farm Activities	MAN-ANIMAL SYSTEM $MAMI_{rice}$ *(hp/ha)*						
	Theoretical Computation	Oriental Mindoro	Remarks	Laguna	Remarks	Quezon	Remarks
Land Preparation	1.376	0.401	*Below Theoretical*	0.369	*Below Theoretical*	1.133	*Below Theoretical*
Crop Establishment	0.594	0.008	*Below Theoretical*	0.103	*Below Theoretical*	0.080	*Below Theoretical*
Crop Care	0.327	0.078	*Below Theoretical*	0.045	*Below Theoretical*	0.993	*Above Theoretical*
Harvesting	0.975	0.500	*Below Theoretical*	0.187	*Below Theoretical*	0.202	*Below Theoretical*
Hauling	0.931	0.014	*Below Theoretical*	0.050	*Below Theoretical*	0.180	*Below Theoretical*
Drying	0.868	0.012	*Below Theoretical*	0.007	*Below Theoretical*	0.058	*Below Theoretical*
TOTAL	5.071	1.013		0.762		2.646	

Table 6. Summary of the computed $MAMI_{rice}$ in man-machine system on the three provinces.

MAN-MACHINE SYSTEM $MAMI_{rice}$ *(hp/ha)*						
Theoretical Computation	Oriental Mindoro	Remarks	Laguna	Remarks	Quezon	Remarks
1.376	1.361	*Ideal*	0.835	*Below Theoretical*	2.538	*Above Theoretical*
0.594	0.049	*Below Theoretical*	0.103	*Below Theoretical*	0.113	*Below Theoretical*
0.327	0.078	*Below Theoretical*	0.045	*Below Theoretical*	0.992	*Above Theoretical*
0.975	1.519	*Above Theoretical*	0.532	*Below Theoretical*	0.592	*Below Theoretical*
0.931	0.010	*Below Theoretical*	0.139	*Below Theoretical*	0.112	*Below Theoretical*
0.868	0.012	*Below Theoretical*	0.007	*Below Theoretical*	0.218	*Below Theoretical*
	3.029		1.661		4.565	

Table 7. Summary of the computed $MAMI_{rice}$ in man-machine system on the three provinces using rototilling and combine harvesting operations.

Farm Activities	MAN-MACHINE SYSTEM $MAMI_{rice}$ *(hp/ha)*						
	Theoretical Computation	Oriental Mindoro	Remarks	Laguna	Remarks	Quezon	Remarks
Land Preparation	1.376	0.668	*Below Theoretical*	0.362	*Below Theoretical*	0.385	*Below Theoretical*
Crop Establishment	0.594	0.049	*Below Theoretical*	0.103	*Below Theoretical*	0.298	*Below Theoretical*
Crop Care	0.327	0.078	*Below Theoretical*	0.045	*Below Theoretical*	0.992	*Above Theoretical*
Harvesting	0.975	0.963	*Ideal*	0.576	*Below Theoretical*	0.500	*Below Theoretical*
Hauling	0.931	0.010	*Below Theoretical*	0.139	*Below Theoretical*	0.112	*Below Theoretical*
Drying	0.868	0.012	*Below Theoretical*	0.007	*Below Theoretical*	0.218	*Below Theoretical*
	5.071	1.780		1.232		2.505	

The AMTs considered in the theoretical values of MAMI are those that are prevalent in the country as noted earlier. For land preparation operations (plowing and harrowing), the AMT considered was 4-wheel tractor. Rice transplanter was considered in crop establishment. Knapsack sprayer, manual weeder, and pump set were considered in the calculation of theoretical MAMI in crop care. Rice combine harvester was used for harvesting while flatbed dryer for drying. For hauling, draft animal

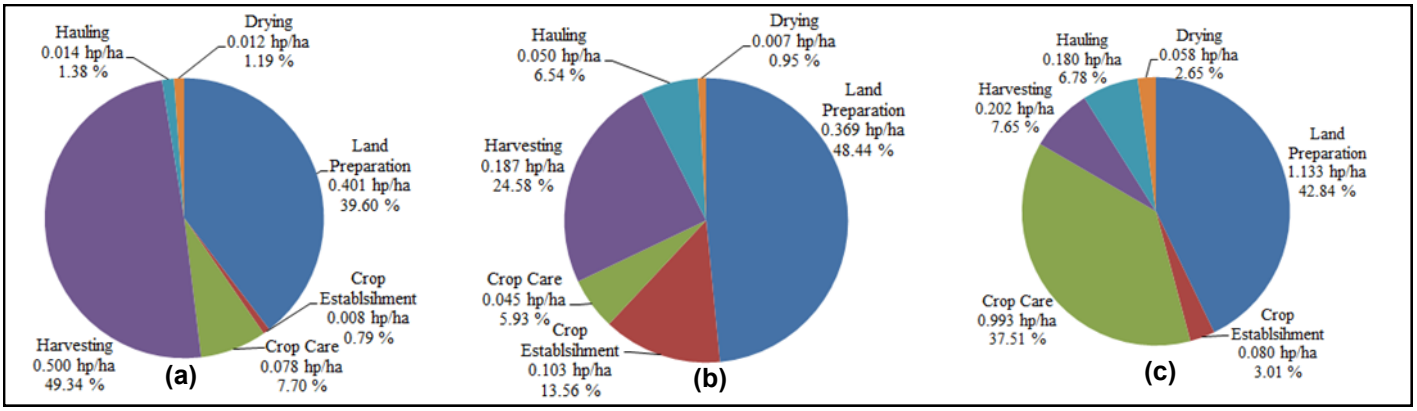

Figure 1. Percentage distribution of each operations in man-animal system in Oriental Mindoro, (b) Laguna and (c) Quezon.

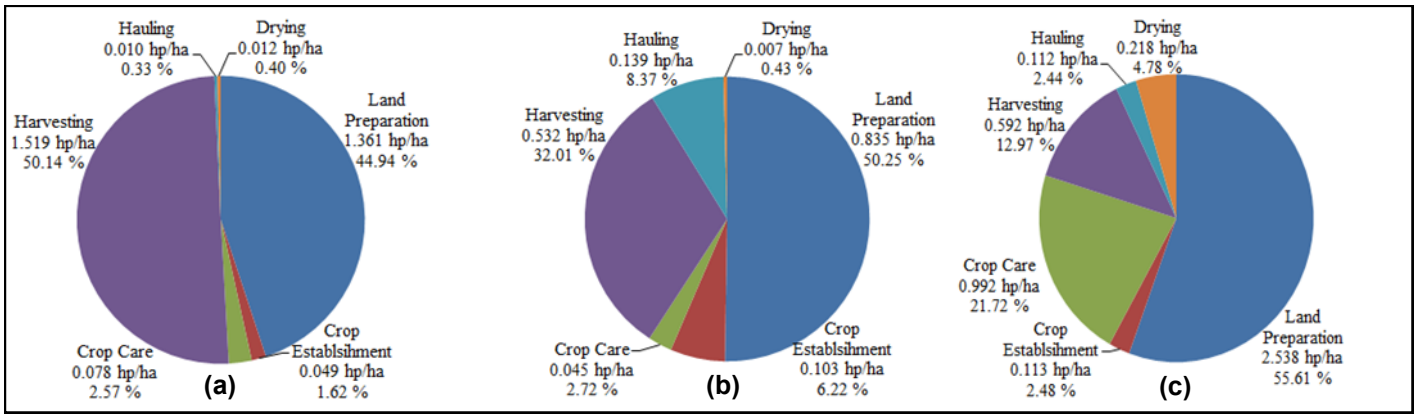

Figure 2. Percentage distribution of each operations in man-machine system in (a) Oriental Mindoro, (b) Laguna and (c) Quezon.

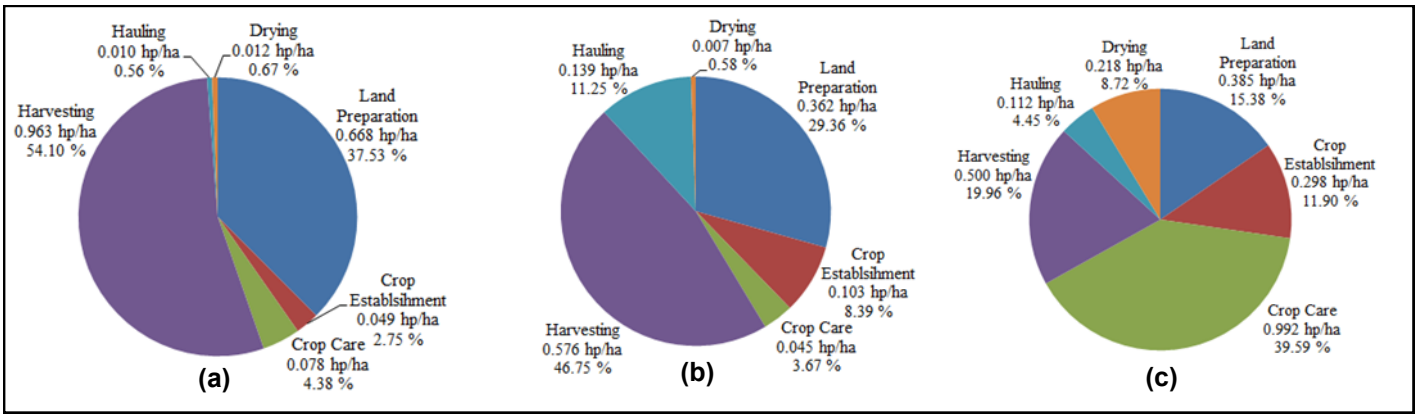

Figure 3. Percentage distribution of each operations in man-machine system using rototilling and combine harvesting operations in (a) Oriental Mindoro, (b) Laguna and (c) Quezon.

was used as power source. The MAMI of the three provinces were compared to the theoretical values obtained using these AMTs. While it may be true that appropriate AMTs should be used for specific operation, farmers' mindset should be geared towards moving up to a higher mechanization level. The government should set a target AMTs for specific operation in the rice production system that can be attained to increase the level of mechanization to the ideal mechanization condition, towards attaining the target rice yield for the country.

Figures 1, 2 and 3 present the percentage distribution of each farm operation using man-animal system, man-machine system, and man-machine system using rototilling and combine harvesting in the three provinces. In Oriental Mindoro and Laguna, land preparation and harvesting operations contributed to the high level of agricultural mechanization while drying operation had the least contribution. In Quezon, aside from land preparation and harvesting operations, crop care operation had also a major impact on the level of agricultural mechanization of the province while crop establishment operation had the least.

In recent years, the government focused its efforts in improving the level of agricultural mechanization through the acquisition and distribution of 4-wheel tractors for land preparation operation and combines for harvesting operation. The results were evident in the three surveyed provinces. Increased efforts on the distribution of drying facilities was also done but as indicated in the survey results, only few farmers adapted and utilized rice mechanical dryers since they prefer to sell their produce to traders just after harvest or perform the traditional practice of solar drying. This could also explain the low contribution of rice dryers in the level of agricultural mechanization for all the surveyed provinces. With this information, planners and decision makers can prioritize which among the farm operations need additional intervention to improve the agricultural mechanization index and the level of mechanization for rice production.

CONCLUSION

The government allocated significant funding in the advancement of agricultural mechanization in the countryside and in realization of the AFMech Law of 2013. Since rice is one of the most important crops in the Philippines, the government focuses more on improving the rice production and postproduction systems by introducing agricultural mechanization technologies to rice producing areas in the country. However, proper allocation and distribution of AMTs requires assessment and monitoring. Hence, the level of agricultural mechanization must be known before and after the distribution of AMTs for rice production. Due to the absence of a common methodology in determining the level of mechanization in the country, BIOMECH in cooperation with the DA-PCAF established the modified agricultural mechanization index for lowland rice ecosystems ($MAMI_{rice}$) to assess the level of agricultural mechanization in rice farming operations.

In this study, the different parameters were obtained to assess the level of agricultural mechanization using $MAMI_{rice}$ equation on selected rice producing municipalities and cities in Oriental Mindoro, Laguna and Quezon provinces through a survey. Using the established equation and the parameters from the survey, $MAMI_{rice}$ for the different farming operations were obtained. The equation can be an effective tool in determining whether what operations need further attention in terms of agricultural mechanization.

Results showed that among the rice farming operations, land preparation and harvesting operations had the highest mechanization index while drying operation has the least. The other farming operations with low AMI should also be considered. AMTs for these operations should be introduced if not enhanced to have an equitable contribution to the total AMI and to achieve the ideal level of mechanization that would contribute in the attainment of target rice production. The study also indicated that many of the engines used in the surveyed sites were underutilized. Thus, high or full utilization of the engines or prime movers for other

farming operations should be considered for effective and efficient utilization of AMTs.

The level of agricultural mechanization index obtained for the three provinces were still way below the computed ideal mechanization index for the country which is 5.071 *hp/ha*. Finally, the study showed that higher agricultural mechanization index does not necessarily correspond to an ideal level of mechanization if the target yield of 6 *tons/ha* is not attained and utilization of the machines is inefficient and underutilized. In these cases, obtaining an agricultural mechanization index that is greater than the theoretically computed values for each farm operation may mean as underutilization of some AMTs. The use of MAMI will aid government and other stakeholders' concerted efforts towards the efficient utilization of AMTs.

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Erratum: Table 6 on page 66 should be corrected as follows:

Table 6. Summary of the computed $MAMI_{rice}$ in man-machine system on the three provinces.

MAN-MACHINE SYSTEM $MAMI_{rice}$ *(hp/ha)*							
Farm Activities	Theoretical Computa-tion	Oriental Mindo-ro	Remarks	Laguna	Remarks	Quezon	Remarks
Land preparation	1.376	1.361	*Ideal*	0.835	*Below Theoretical*	2.538	*Above Theoretical*
Crop establishment	0.594	0.049	*Below Theoretical*	0.103	*Below Theoretical*	0.113	*Below Theoretical*
Crop care	0.327	0.078	*Below Theoretical*	0.045	*Below Theoretical*	0.992	*Above Theoretical*
Harvesting	0.975	1.519	*Above Theoretical*	0.532	*Below Theoretical*	0.592	*Below Theoretical*
Haulig	0.931	0.010	*Below Theoretical*	0.139	*Below Theoretical*	0.112	*Below Theoretical*
Druing	0.868	0.012	*Below Theoretical*	0.007	*Below Theoretical*	0.218	*Below Theoretical*
		3.029		1.661		4.565	